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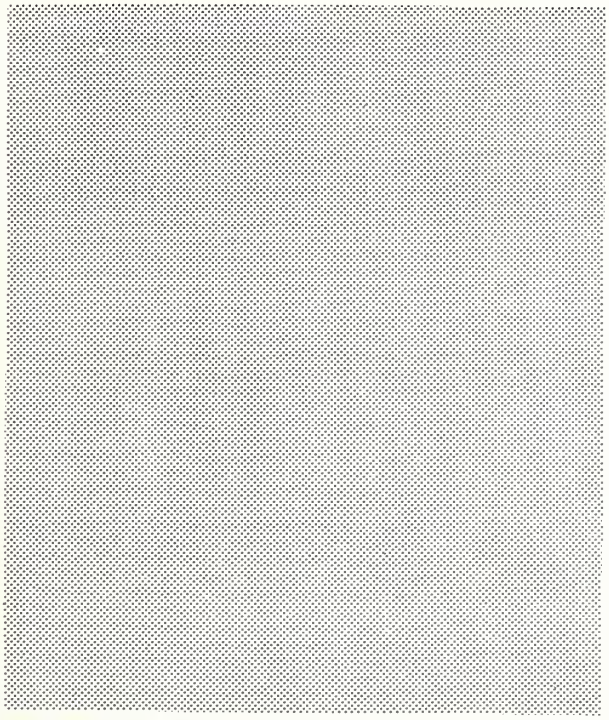
FREEZE-DRYING OF FOOD-- A LOOK INTO THE FUTURE



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FREEZE-DRYING OF FOODS - A LOOK INTO THE FUTURE 1/

Freeze-dried food gained national attention recently from its use by high-altitude mountain climbers. It also has been used by our astronauts in space flights. This new processing method offers promise of growing into a multi-million-dollar industry in a few years. Freeze-dried foods may be stored 2 years or longer at room temperatures. Quickly and easily rehydrated, they maintain a high degree of flavor.

This article (1) describes the advantages and limitations of freeze-drying, (2) reports some results of USDA research on taste acceptability of freeze-dried foods and probable costs of processing specified volumes, and (3) on the basis of research, suggests some prospects for commercial development of the process.

What is Freeze-Drying?

Food to be freeze-dried is first blanched, cooked, or processed in other ways. Then, to facilitate drying, it is cut into small pieces, and they are individually quick-frozen conventionally. The frozen food is placed in a drying cabinet where the pressure is lowered. Heat is applied to the food so the ice sublimates, always maintaining a frozen product. 2/ Water in the form of vapor is removed from the cabinet; when the moisture level in the food has been reduced to about 2 percent, the process is complete.

The final product is a dried, not a frozen food. Thus dehydrated, it may be kept without refrigeration, although it must be tightly packaged to keep out air and moisture. Drying may require 6 to 22 hours, depending on the product and the temperatures and pressures used. However, for most foods an 8 to 12 hour drying cycle is adequate -- providing the food is no more than three-eights of an inch thick and no more than about 3 pounds of food per square foot of cabinet shelf area are dried. This need for small particle sizes in drying may be a disadvantage, since some foods lose their appeal when fragmented. It is theoretically possible, although costly, to dry a large unit of food such as an egg, a roast, or a whole turkey.

This drying technique is not new, having been used many years in biology, medicine, and pharmacy. 3/ The technique is employed in preparing blood plasma and pharmaceuticals, and for drying skin and bone tissue, insects and small animal specimens. The Smithsonian Institution has an exhibit on these techniques applied to museum use. Investigating possibilities of freeze-drying are manufacturers of dairy products who dry cultures and animal breeders interested in semen handling.

Until the last decade, the method was too expensive to use in preserving food. Recent innovations in drying techniques have shortened drying time, however, so many food processors and handlers are interested now. Although costs are still comparatively high, they are within the

1/ Prepared by Kermit Bird, agricultural economist, Marketing Economics Division, Economic Research Service.

2/ Sublimation is the physical change of a solid to a vapor, bypassing the liquid phase.

3/ The newness of its application to foods is shown in a bibliography Freeze-Drying of Foods, A List of Selected References, July 1963, National Agricultural Library List 77, USDA. Only 3 books are listed on freeze-drying of foods. However, the bibliography includes titles of over 700 journal, periodical, and magazine articles.

Single copies of publications cited in this article may be obtained by writing to the Division of Information, Office of Management Services, USDA, Washington, D. C., 20250.

range of possibility for higher-value foods, foods for specialized uses, and dried foods for which good flavor is especially desired.

Advantages and Limitations of Freeze-Drying

Freeze-dried foods retain many physical characteristics of the frozen foods from which they are derived. Because cellular structure is maintained, the physical state of the rehydrated food is about the same as thawed frozen food. Much original flavor remains since most flavor-carrying oils are not removed in sublimation. Some water-soluble flavors, however, are lost. Flavor loss is a common problem in other food drying techniques, particularly those using heat; and freeze-dried foods generally taste better than other dried foods. In addition, they rehydrate faster than most conventionally-dried foods.

Freeze-dried foods have the advantages of all dried foods, except they are more bulky. They are stored and transported without refrigeration, are lightweight, and have long shelf life. These advantages, coupled with flavor retention capacity, give freeze-dehydrated foods an enviable position among processed products.

On the negative side, freeze-drying is slow; and, as a consequence, costs are high. Freeze-drying equipment is expensive; the newness of the industry suggests a high equipment obsolescence, which dictates a fast write-off in depreciation.

Another limitation is that expensive containers are needed. An airtight, moisture-resistant, and light-proof package is needed, and packaging must be done promptly. Entry of oxygen or water into the package shortens the life of the product; hence, a can or tight, laminated-foil pouch is indicated. Many freeze-dried foods are vacuum or nitrogen packed to keep oxygen levels at a minimum. This adds to packaging expense.

Desirable Foods for Freeze-Drying

In general, foods that freeze well are suitable for freeze-drying. Foods high in sugar or fat content, like fatty pork, do not freeze easily and are difficult to freeze-dry. However, such products as lean pork, avocadoes, and cream cheese are freeze-dried successfully. Foods that lose their physcial structure when frozen and thawed make poor freeze-dried foods. Examples are melons, tomatoes, and lettuce. But these may be freeze-dried successfully where retention of physical structure is not important, as in tomato puree.

Freeze-drying seems best adapted to meats, especially poultry and beef. Fishery products, including shellfish, also dry nicely. Most vegetables, fruits, berries, mushrooms, spices, and seasonings are dried successfully. Some dairy products including cottage cheese, dips, cheeses, and beverages seem well adapted.

Main Uses of Freeze-Dried Foods

The largest purchaser of freeze-dried foods is the U. S. Armed Forces. Many foods suited to special military uses have been developed by Quartermaster personnel. Because of their long shelf life and high quality, freeze-dried foods are now planned as basic ingredients of the new combat rations, the "Quick Serve" and the "Meal Ready to Eat." Both rations include freeze-dried items that were cooked before drying. Some freeze-dried foods, mainly beef, pork chops, and fish squares (uncooked) are being purchased in large quantities for mess usage. Military subsistence this year is taking bids for 210,000 pounds of dried meats. This is equivalent to about a half-million pounds of rehydrated foods.

The institutional market is portion-control and quality conscious. Recent sales of freeze-dried shrimp, crab, and chicken indicate this market may be an important outlet for many of these foods.

The "mix" market promises to absorb large quantities of freeze-dried foods. The entire output of several freeze-dry processing plants consists of chicken dices, beef dices, and mushrooms for dry-soup mixes. These freeze-dry pieces are mixed with other dried ingredients in the soup sold to the public. Other mixes now on the market include chili, creoles, and a mixture of sausage and scrambled eggs. Freeze-dried eggs, by the way, are notably superior to spray-dried eggs used by the military in World War II.

The market for specialized products such as spices, seasonings, extracts, and beverages may well become important. These products retain a very high proportion of their original flavor when freeze-dried. Also included may be dried berries and fruits to be used in bakery foods, ready-to-eat cereals, cake mixes, gelatin desserts, and puddings. At present, one U. S. company is preparing to freeze-dry coffee, and in Brazil another firm is tooling up for coffee-extract dehydration. Several concerns abroad freeze-dry tea.

Another specialized use of freeze-dry items is for the camping trade. Fifteen or 20 prepared dishes are on the market in sporting goods stores. Prices are high. Volume, although small at present, shows signs of increasing.

Growth of the Industry

A year ago 6 freeze-drying plants were operating in the United States and Canada. Now there are 12, with a combined capacity of about 50 to 60 tons of raw product per day. This comparison typifies growth of this new, but rapidly expanding, industry. In the British Isles there are 5 plants. There are 13 on the Continent. Several in other areas of the world complete the roster of about 32 plants commercially producing foods. 4/ Other plants are under construction, and several now in business are enlarging their facilities.

The largest volumes of freeze-dried items in world production are chicken pieces, meat pieces and slices, mushrooms, and vegetable pieces. 5/ Most are used in dried soups. Other foods include seafoods (especially shellfish), fruits and berries, extracts, and beverages.

Some companies freeze-dry foods for use in products they manufacture and market. Ingredients for soup mixes are an example. Other companies dry and sell freeze-dried items for blending or mixing. Most U. S. firms do contract work for the Government. Two U. S. firms and one in Canada do custom drying. In this operation the customer supplies the product to be dried and may also freeze and package the food. No pattern has emerged as to the type of operation likely to prevail in the future. Several types probably will exist, as is the case in the canning and freezing industries.

Results of Research

The rapidity of the industry's growth, and even its survival, will depend on its ability to manufacture and sell products that will (1) achieve a stable and relatively extensive volume of production, (2) be cost competitive with canned, dehydrated, and frozen products, and (3) be in a form readily handled by the marketing system. Research results may provide answers to these questions and an economic understanding of whether the future of freeze-drying is promising. Here are some results of USDA research on freeze-drying:

4/ For a complete listing of freeze-dry processors and freeze-dry equipment manufacturers, see A Directory of Freeze-Drying, April 1963, Kermit Bird, Marketing Economics Division, ERS-USDA.

5/ For poultry industry prospects see: Freeze-Dried Poultry, F-D Report No. 3, January 1963, Kermit Bird, Marketing Economics Division, ERS-USDA, Washington, D.C.

Taste Tests.--During the past year all commercially available freeze-dried foods were tested by an experienced taste panel. 6/ Although results are not conclusive and are not meant to be final evaluations, they give indications of the general level of palatability of freeze-dried foods. Each test food was compared with a similar canned or frozen food.

Freeze-dried items included beef, pork, chicken, seafoods, soups, and mixtures. Palatability of most foods tested was acceptable, according to the panel. Compared with other processed foods, 3 freeze-dried foods were considered superior, 15 were about the same, and 10 were inferior. Freeze-dried foods rated superior were beef noodle soup, chicken noodle soup, and shrimp creole. Those having commendable scores were creamed chicken, ham, sausage, swiss steak, shellfish, and several soups.

Figure 1 shows taste panel results of a representative group of 6 foods. Average panel scores of freeze-dried and conventionally processed foods are compared.

Freeze-dried foods received higher scores when used in prepared mixes than when served plain. Other ingredients and spices in the prepared dishes seemed to offset flavor deficiencies in some freeze-dried foods.

If the ratings of this experienced taste panel are indicative of public acceptance, large-volume production of freeze-dried foods appears feasible. Their chief market, however, may involve competition with conventionally dried foods, which also are similar in usage, lightweight, have long shelf life, and may be stored without refrigeration.

Although freeze-dried foods have some of the quality attributes of frozen foods -- they retain more original physical structure, flavor, and nutritive value than air-, heat-, or vacuum-dried foods -- they are not all-inclusive substitutes for frozen or canned foods. This limits their competitive position in relation to products from these long-established processing industries.

Processing Cost.--Information from a USDA cost study shows that freeze-dry processing may cost from 3 cents to 20 or 30 cents per pound of water removed. In the future, costs may stabilize at about 3 to 7 cents per pound of water removed -- depending on the individual product. 7/

The general purpose of the cost study was to examine costs and analyze factors affecting these costs. These include length of season, hours per day of plant operation, type of product being processed, wage and utility rates, and length of drying cycle. Costs of 4 model plants were developed and organized so effects of these factors could be studied.

Excluding costs of raw materials and packaging, the largest single expense of small freeze-drying plants is labor -- about one-third of total costs. In large plants that are more fully automated, depreciation of equipment is the large expense item -- 40 percent of total costs. Utility costs range from 17 to 20 percent of total costs.

If a small modern plant is operated at full daily capacity for 250 days per year, average costs of freeze-drying chicken are 6 to 7 cents per pound of water removed. In a larger plant under the same conditions, average costs are 4 to 6 cents per pound. These estimates are for plants using 8-hour drying cycles. Where a 12-hour cycle is used, comparable costs range from 4.6 to 8.3 cents per pound of water. Similar costs were calculated for other food products, and they

6/ Complete results are reported in Freeze-Dried Foods: Palatability Tests, MRR-617, July 1963, Kermit Bird, Marketing Economics Division, ERS-USDA.

7/ For a complete analysis of freeze-drying costs see Freeze-Drying Costs, a bulletin to be released soon, Kermit Bird, Marketing Economics Division, ERS-USDA.

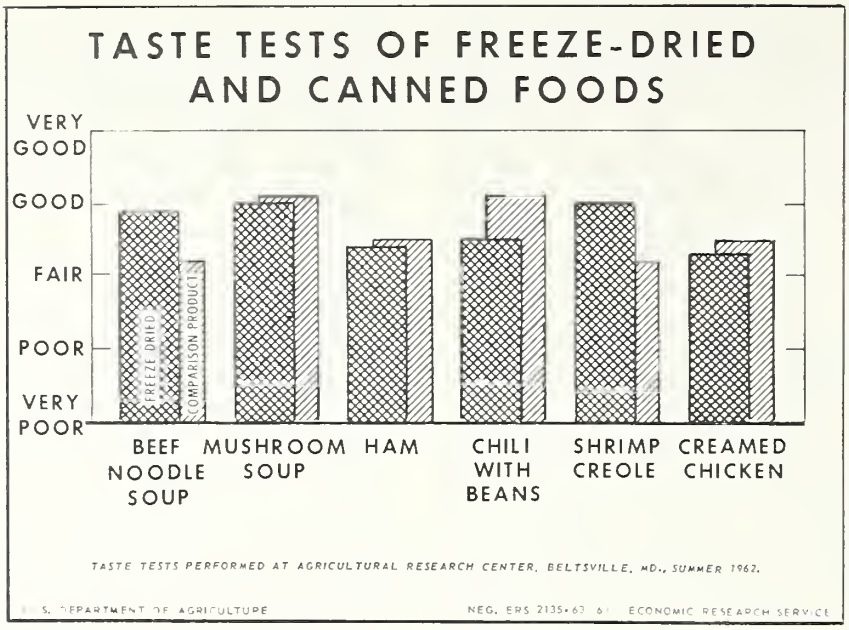

Figure 1

varied in relation to the proportion of water in the raw product to be dried. The accompanying table shows costs for chicken, beef, shrimp, and mushrooms. Note that costs per pound of water removed vary from 6.2 to 7.6 cents per pound (table 12, center column). Costs per pound of input product (the frozen food) are lower, about 4 to 5 cents per pound lower. Thus, freeze-dried chicken will have higher prices than comparable frozen or canned chicken. Costs per pound of freeze-dried food are much higher; as an example, mushroom weights are reduced very much, and cost of the dried product is 45 cents per pound.

Length of season, as in all food processing operations, is an important determinant of freeze-drying costs. For example, if one of the model plants processed shrimp 350 days per year, costs were 3.3 cents per pound. If the plant were operated only 100 days per year, costs were 7.2 cents per pound of water removed.

Hours of daily operation affected costs significantly. A plant operated 24 hours a day had costs of 5 cents per pound of water removed. The same plant operated 16 hours per day had average costs of 7 cents per pound. An 8-hour day operation showed costs averaging 11 cents per pound.

In general, low freeze-dry processing costs may be attained by plants able to handle large volumes of food. A large-capacity plant capable of removing 32 tons of water per day (equivalent to 35 to 40 tons of raw product) will have much lower costs than smaller plants. To keep costs low, plants also need to operate steadily throughout the day and season. In most production areas a large-capacity plant would need to process a variety of foods to obtain its needed volume. To attain minimum cost, a drying plant may need to operate in conjunction with a more complete processing complex that might include food preparation, freezing, storage, packaging, and warehousing.

Table 12.--Estimates of freeze drying costs of 4 freeze-dried foods 1/

Food to be dried	Cost per pound of--		
	Frozen food (input)	Water removed	Dried food (finished product)
	Cents	Cents	Cents
Chicken, cooked dices, 56 percent moisture	4.1	7.6	8.9
Beef, cooked dices, 60 percent moisture	4.4	7.6	10.4
Shrimp, cooked and deveined, 70.4 percent moisture	5.1	7.5	16.2
Mushrooms, blanched raw, 90 percent moisture	5.5	6.2	45.4

1/ Costs pertain to plants with a water-removal capacity of 4 tons per day and operating under these conditions: 24 hours per day, 250 days per year, 8-hour drying cycle. Equipment depreciation is 14 percent. Midwest labor and utility rates are assumed.

The Future of Freeze-Drying.--We may summarize results of the taste and cost studies as follows: The market for freeze-dried foods currently is limited to individual items since the process is not applicable to all foods. Foods that appear to have the greatest volume potential are those that may be used in mixes such as soups, stews, prepared meals, and dairy dips. In addition, there are certain seafoods and items used for special purposes that appear promising.

Costs of freeze-drying are high at present, but may be expected to decline to a range of 3 to 7 cents per pound of water removed, depending on volume of operation, wage rates, utility rates, and moisture level of the food processed. Even with costs this low, the potential use of the process is limited to high-value and specialty foods.

This discussion is based on the implicit assumption that present technologies will be continued. It is likely that innovations in processing techniques will lower costs below the expected levels. As an example, our figures are based on a batch process. Newly developed large-volume, flow-process plants are now being engineered, and lower costs may result. Also, as more product testing is done, there is a good prospect that quality of the freeze-dried items will improve.

With these determinations as guides, we may anticipate the future of the industry. First, there does not appear to be an immediate retail market for many of these foods sold as individual items. Sales to the armed forces appear to be the largest market for the products. The second market is for "mixes." The third one is for items used in remanufacturing. The fourth is for specialty items like extracts, seasonings, and spices. The fifth outlet is in freeze-dried coffee, tea, and concentrates. And finally there is the camping market. While small in total, it may be important to individual firms.

Based on test results, we conclude that:

(1) There is a definite future for the freeze-drying industry. This future will be in the products discussed above and products yet to be developed.

(2) The future growth rate of the industry is uncertain. However, if present interest continues, volume

may double or triple each year for the next few years. If so, the volume by 1967 could well be 400 to 500 million pounds of raw input product annually -- about 2 percent of the processed food volume. This is not large, compared with present food freezing and canning industries, which have annual volumes of about 7 billion and 19 billion pounds, respectively. 8/

8/ In 1961, canned food volume (excluding seafoods) totaled 19.3 billion pounds, as follows: Fruits, including pineapple, 4.7 billion; juices, including pineapple, 2.8 billion; vegetables, 8.8 billion; poultry meats, 0.6 billion; and red meats, 2.4 billion. In the same year the volume of frozen food (excluding seafoods) amounted to 6.7 billion pounds, as follows: Fruit and juices, 1.7 billion; vegetables, 2.3 billion; poultry meats, 2.3 billion; and red meats, 0.4 billion.